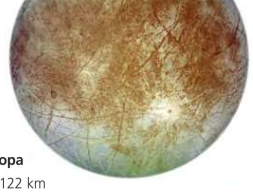
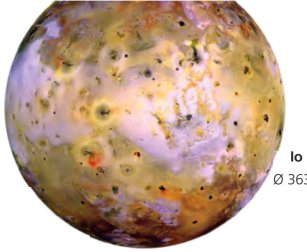
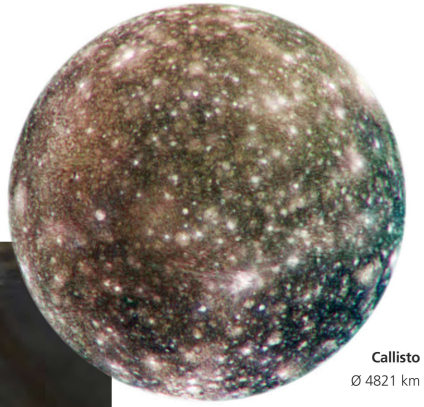


Europa
Ø 3122 km



Io
Ø 3631-3660 km



Callisto
Ø 4821 km

ESA/ATG medialab; NASA/JPL/DLR/ESA

OF DISTANT MOONS AND OCEANS

Two DLR instruments will investigate Jupiter's icy satellites

By Ulrich Köhler

2022 will see the launch of the Jupiter Icy Moon Explorer, the first mission of the European Space Agency (ESA) to study the outer Solar System. JUICE is a mission of ESA's Cosmic Vision programme. On board are 10 scientific instruments, including JANUS and GALA, in which DLR is heavily involved. When it arrives in the Jovian system in 2031, JUICE will explore three fascinating worlds of ice, rock and water – the moons Europa, Ganymede and Callisto.

In 1610, the great Tuscan polymath Galileo Galilei first observed and documented moons in orbit around Jupiter – and the first objects to orbit a planet other than Earth. In doing so, he confirmed the Copernican, heliocentric world view, which states that Earth is a planet like the others, and that they all revolve around the Sun. The Jovian moons were named after favourites of Zeus – Io, Europa, Ganymede and Callisto – and have since become known as the 'Galilean' satellites in honour of their discoverer.

Remarkable companions of a colossal planet

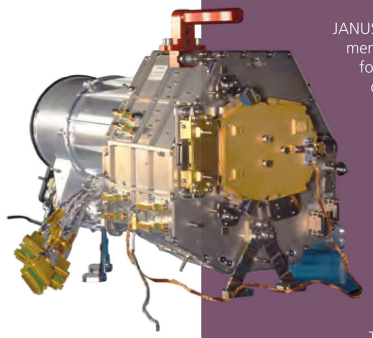
Examined by spacecraft at close range for the first time in 1973/74 during the Pioneer 10 and 11 missions, the four moons were studied in much greater detail in 1979 during the flyby of Voyager 1 and 2. The images we received revealed fascinating and very different worlds. Io, the innermost of the four Galilean satellites, is one of the most volcanically active bodies in the Solar System. High-sulphur lava at temperatures of up to 1350 degrees Celsius is spewed, giving the moon its surreal, yellow appearance. On the other hand, Europa, which is roughly the same size as the Earth's Moon, resembles a smooth sphere of ice riddled with hundreds of fractures and a temperature of minus 170 degrees Celsius. Then there's Ganymede. With a diameter of almost 5300 kilometres, it is the largest natural satellite in the Solar System. Beneath its icy shell are a rocky mantle and an iron core – which creates a distinct magnetic field, the only one found so far on a natural satellite. Last but not least is Callisto. The somewhat smaller moon is littered with thousands of impact craters. Under its icy crust, a mixture of stone and iron seems to indicate a barely differentiated body, geologically inactive very early on.

Are there oceans on Europa and Ganymede?

NASA's Galileo orbiter explored these four worlds between 1995 and 2003. In addition to the four large moons, 75 other satellites, some only a few kilometres in size, orbit the 140,000-kilometre-diameter gas giant. The spacecraft sent back reliable evidence to support the hypothesis that oceans must exist under the kilometre-thick ice crusts

Ganymede
Ø 5268 km

Moon images: NASA/JPL/DLR



LDO

JANUS

JANUS is the camera system selected by ESA to fulfil the optical imaging scientific requirements of the JUICE mission. Short for Jovis, Amorum ac Natorum Undique Scrutator (Latin for 'comprehensive observation of Jupiter, his love affairs and descendants'), JANUS was developed in Italy, Germany, Spain and the United Kingdom. Parts of the hardware were built at the DLR Institute of Planetary Research, which also provides one of the scientific leads, Thomas Roatsch. The main electronics were developed at the Institute for Data Technology and Communications Networks at the TU Braunschweig.

One of the primary tasks of JANUS is mapping, that is, optically recording the landscapes of Ganymede and Europa and the effects of tidal forces that might be visible on their surfaces, which are responsible for the formation of the subcrustal ocean layer. In addition to a high spatial resolution, the camera system has a broad spectral range and high radiometric (light) sensitivity across 13 spectral filters. Light signals are recorded at wavelengths from 340 nanometres (blue) to 1100 nanometres (near infrared). Io and many of the small moons will also be observed from a distance.

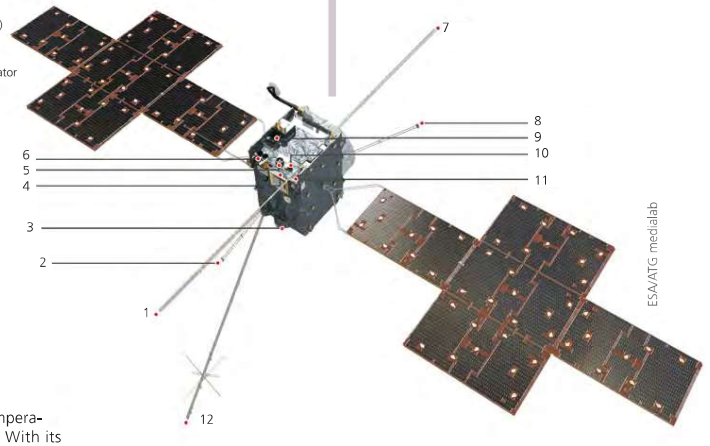
The high sensitivity is guaranteed by the powerful optics and the sensitive detector and electronics unit. JANUS has an extremely sensitive light detector that can withstand the high levels of radiation encountered in the Jovian system. The readout electronics developed for this purpose at DLR are extremely low-noise.

EXPERIMENTS ON BOARD JUICE

1/7	RIME	Radar for Icy Moons Exploration
2/8	RPWI	Radio & Plasma Wave Investigation
3/9	PEP	Particle Environment Package
4	MAJIS	Moons and Jupiter Imaging Spectrometer (visible-near infrared hyper-spectral imager)
5	GALA	Ganymede Laser Altimeter
6	SWI	Sub-millimetre Wave Instrument
10	JANUS	Jovis, Amorum ac Natorum Undique Scrutator (camera system)
11	UVS	UV Spectrograph
12		Magnetometer beam with RPWI and J-MAG Magnetometer for magnetic field measurement

IN THE SPACECRAFT

3GM: Gravity & Geophysics of Jupiter and Galilean Moons (radio-science)

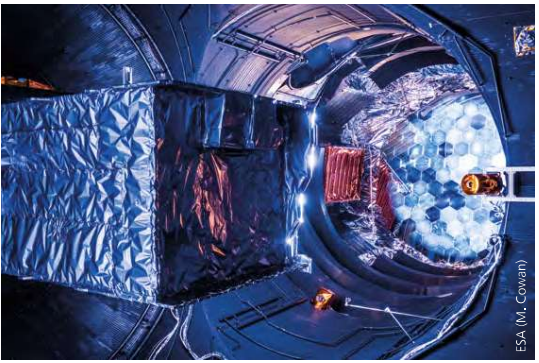


ESA/ATG medialab

of Europa and Ganymede. These could contain more water than all of Earth's oceans, and possibly even harbour life! Europa's sub-crustal ocean sometimes appears to be ejecting water onto the surface along fractures – the numerous lines in the ice are reminiscent of blade marks left by skaters – where it quickly freezes, yielding an ever-rejuvenating and changing landscape.

How is this possible, so far from the Sun, at temperatures well below minus 100 degrees Celsius? With its enormous mass, Jupiter exerts extremely strong tidal forces on its four largest moons, which deform the satellites, 'kneading' them from the inside and creating heat through friction. This heat keeps the salty water above freezing point. Io, Europa, and Ganymede are locked in a 4:2:1 orbital resonance. This means that the moons are repeatedly lined up like a string of pearls, which intensifies the tidal effect and generates even more heat. Scientists are fairly certain that warm ocean water circulates under Europa's icy crust and through the rock shell, releasing minerals that are washed onto the surface along with the water. The Galileo space probe spectroscopically detected mineral salt deposits on the ice.

Water, heat, salts – these are some of the most important prerequisites for the emergence and existence of life. Europa and Ganymede have long been considered potential habitats for microbial life beyond Earth – in an environment completely different from that of Mars, where intensive searches for traces of former (and perhaps even present) life are currently under way. This makes the Jovian system a natural target for further exploration.



ESA (M. Cowan)

A view of the JUICE Thermal Development Model (TDM) inside the Large Space Simulator at ESA's European Space Research & Technology Centre (ESTEC)

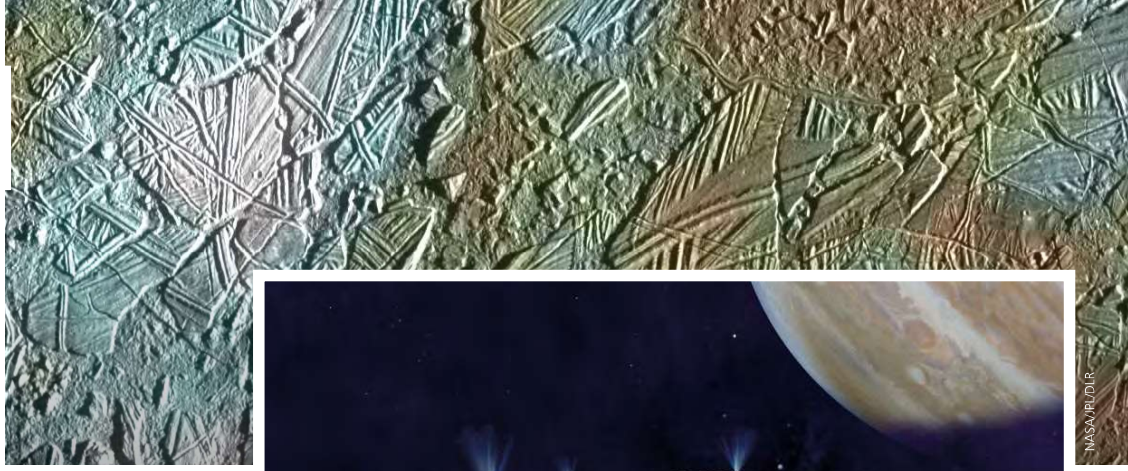
Hidden seas and unique magnetic fields

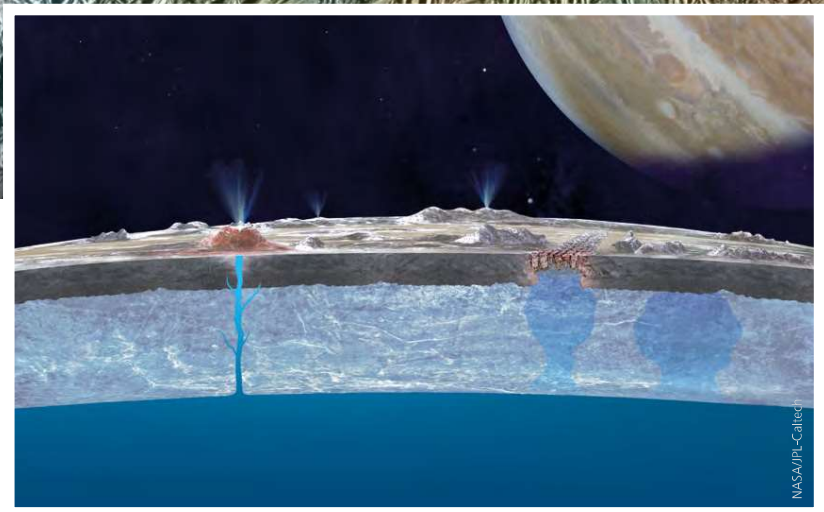
JUICE will conduct detailed studies of Jupiter and its system in the 2030s. The focus of the mission is to find out how these potentially life-friendly environments formed under the icy crusts of the gas giant's moons, and what they look like today. The focus is on the hidden seas of Ganymede and Europa, and possibly also Callisto. As a quasi-planetary body and a potential habitat, Ganymede will undergo the most detailed study. It is a great laboratory for analysing the nature, evolution and potential habitability of icy worlds. It is also of interest due to its unique magnetic field and plasma interactions with the Jupiter environment. Investigations of Europa and Callisto will complete the investigation. Jupiter itself is the archetype for the gas giants of the Solar System and therefore also for the thousands of giant exoplanets now known to orbit other stars.

A winding path through space

But these events are a long way off. The ESA spacecraft is currently being prepared in Toulouse, at Airbus Defence and Space, for its launch on an Ariane 5 rocket in the autumn of 2022. The instruments have already been put through their paces and calibrated, have received the demanding spaceworthiness certification, and are currently being installed on the spacecraft. The journey through space to Jupiter, whose orbit is located approximately 780 million kilometres from the Sun, is expected to take almost eight years, and will require four flybys of Earth and one of Venus. Finally, the JUICE spacecraft will spend eight months orbiting Ganymede, during which it will make detailed investigations of the moon and its surroundings, and will eventually impact on the surface.

Ulrich Köhler is a planetary geologist at the DLR Institute of Planetary Research in Berlin-Adlershof. He has fond memories of the arrival of NASA's Galileo space probe at Jupiter in 1995.





NASA/JPL/DLR

NASA/JPL-Caltech

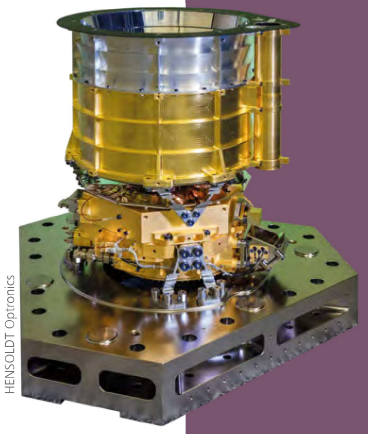
Broken, displaced and rotated ice blocks, partly covered by coloured mineral salts (top image), are clear evidence of an ocean beneath Europa's ice crust (right image). From the latter, salty water is forced onto the surface, where it freezes and reacts with sulphur from volcanic eruptions on Io.

GALA

The Ganymede Laser Altimeter (GALA) was developed under the responsibility of the DLR Institute of Planetary Research and was built in cooperation with industrial partners (HENSOLDT Optronics GmbH, Oberkochen) and research institutions from Germany, Japan, Switzerland and Spain. This is the first time that such an instrument will be used in the outer Solar System. The Principal Investigator is Hauke Hußmann of the DLR Institute of Planetary Research.

GALA will measure the tidal deformation of Ganymede's ice crust, and thereby its shape, to provide possible clues to the existence of a planet-wide inner ocean. In addition, an extensive map of the entire regional and local topography of Ganymede will be created, which should help us understand the processes that formed this moon. Tidal deformations will be determined from measurements made at different times during Ganymede's seven-day orbit around Jupiter. The height of the tidal deformation can be used to prove the existence of the inner ocean and to determine the mechanical properties of the ice layer above it. The experiment will also record measurements for Europa and Callisto. It is hoped that observations of Europa will yield evidence for the existence of liquid water just below the surface.

GALA consists of two electronic units and an optical part, which contains the laser and the telescope for the receiver. Laser pulses in the near infrared are sent 30 to 50 times per second from a height of 500 kilometres to the surface of Ganymede to make altitude measurements. A highly sensitive detector then records the reflected pulses. Because GALA can measure the time of flight with an accuracy of less than a nanosecond, the position and alignment of the probe can be determined with great certainty, and Ganymede's surface can thus be scanned at a very high optical resolution. The data will be used to produce a global elevation model.



HENSOLDT Optronics